THE RELATION

OF THE

KANSAS WATER COMMISSION

TO THE

FLOOD PROBLEM OF KANSAS

BY

PROF. H. A. RICE and ROGER C. RICE

January, 1918

Paper Read before the Kansas Engineering Society, at the Tenth Annual Meeting, held at Kansas State University, Lawrence, Kansas, on January 15 and 16

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Prepared in cooperation with United States Geological Survey

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INTRODUCTION.

The patriotic response by the citizens of Kansas to the national appeal to increase the acreage planted to grain for 1918 has been reported in detail by the U. S. Department of Agriculture, Bureau of Crop Estimates, by Edward C. Paxton, field agent for Kansas, in his report dated December 19, 1917, which states in part as follows:

> "Indications are that 9,480,000 acres were seeded to winter wheat in Kansas this fall. This is within one percent of as large an acreage as was seeded in the fall of 1916, which was the largest ever planted to this crop in the history of the state. Kansas farmers undoubtedly did their best to come up to the 10,000,000-acre mark recommended for them by the United States Department of Agriculture."

As the agricultural situation of Kansas is closely interrelated with the partially solved water problems of the state, it seems desirable for such an organization as the Kansas Engineering Society to consider some of the contributing causes for the recent adoption by the state of a constructive state-wide water-conservation policy and the tremendously important part it will play in the development of a more secure agricultural prosperity.

War conditions, in their relation to the food supply of the nation, demand not only that the crops planted in Kansas shall be larger than ever before attempted, but that their ultimate yield shall be as certain as modern scientific farming and the science of engineering can make them, for failure in this or next season's food supply means not merely financial loss at home, but a weakening of our first-line defenses and those of our allies. The failure becomes not only sectional, but national and international in its effect. The time has now come when the state must work toward greater protective measures to insure the agricultural output from disastrous consequences resulting from unfavorable climatic conditions which can be

controlled through the application of engineering, that some of the annually present unknown factors may be eliminated from the forecast of the crop yields.

Each season brings with it the same uncertainties—possible floods and droughts. As much of the cultivated land lies along the fertile river bottoms that annually are liable to overflow, the control of the flood waters on these rivers and their tributaries is one of the consequences that demands early solution. This is, as you readily perceive, a proper subject for Kansas engineers to seriously consider, that they may give to agriculture the assistance that the science of engineering has rendered so effective in the accomplishment of those modern miracles that are the wonder of the arid West.

The machinery for such a state-wide water-conservation policy has already been provided by the last state legislature in the creation of the Kansas Water Commission for the investigation and control of the water problems of Kansas, with power to coöperate with similar federal organizations. This is, as you are aware, a big step forward toward the ultimate solution of the complex problems that are holding back our state-wide agricultural development.

It now becomes necessary for the next legislature to perfect the Water Commission organization by providing an adequate appropriation for its work, in order that it may proceed on a scale commensurate with the importance of the investigations. The present critical food situation serves only to emphasize the need for the speedy accomplishment of this work.

Time will not permit of the discussion of all phases of the water-conservation policy in detail and their bearing on the agricultural situation. The one phase selected for this discussion, "The relation of the Kansas Water Commission to the flood problem of Kansas," it is hoped, will stimulate a broader perspective with which to meet these new war-time economic problems of Kansas involving the utilization of the undeveloped water resources of the state.

DISASTROUS FLOODS IN KANSAS.

Occasional heavy floods have occurred in the valleys of eastern Kansas at infrequent intervals, which have been the subject of much investigation by various state and federal organizations. The years 1844 and 1903 are associated with exceptionally disastrous floods in the Kaw Valley (Pl. I). Floods of

KANSAS RIVER AT TOPEKA DURING 1903 FLOOD.

lesser magnitude, but of widespread loss and injury to property, have occurred in the interim, the most recent being that of 1915. The Marais des Cygnes and Neosho river valleys have also been subjected to serious floods at frequent intervals, which have caused great damage and loss to growing crops and injury to other property. Among those that have occurred may be noted the floods of 1826, 1844, 1885, 1903, 1904 and 1909.

Judging from the experience of the past flood history of Kansas streams, it may be safely predicted that the flood problem will increase in seriousness with each succeeding year, as the country is now being more thickly settled and improved. It is logical to inquire why eastern Kansas is subject to floods, in order that a better understanding may be had to provide adequate protection. Let us, therefore, consider briefly some of the more important factors contributing to flood discharge, and review the dominating characteristics of the drainage areas of Kansas streams.

FACTORS DETERMINING MAXIMUM DISCHARGE.

The maximum discharge of a stream depends on several factors or conditions, among the most important of which are the following:[1]

"1. Extent, duration, and intensity of precipitation, especially the latter in the case of small drainage basins.

"2. Direction of motion of the storm causing the flood. If the storm moves in the direction of flow of the stream the intensity of flood will be greater than if it moves in the opposite direction or across it.

"3. The amount of snow on the ground and the temperature during the storm. Large floods are often due largely to melting snow when the ground is frozen, and in such cases the run-off is much larger than the rainfall.

"4. The storage, both natural and artificial, in the drainage basin. Storage spreads the flood over a larger period and thus reduces the maximum rate of flow.

"5. The size of the drainage basin. Rain storms of great intensity generally cover a comparatively small area, and a larger part of a small drainage basin is more likely to be covered by a very intense storm than of a larger basin. The maximum discharge per square mile will, therefore, increase as the size of the drainage basin decreases.

"6. The physiography of the drainage basin. The maximum rate of flow from a comparatively long and narrow drainage basin, with tributaries entering a considerable distance apart, will be less than from a

1. "Factors determining maximum discharges," by E. C. Murphy, in "Destructive floods in the United States in 1904," Water-supply and Irrigation Paper No. 147, U. S. Geological Survey, pp. 182-183.

basin of nearly circular shape of the same size, but with the tributaries entering the main stream in close proximity. Steep, impervious, deforested slopes of drainage basin, steep slope of bed of tributaries, and small slope of main stream, intensify flood flow.

"Among the more or less artificial conditions that increase the flow may be mentioned controlled storage in the basin; deforestation and cultivation; reduction in width of channel by placing abutments of bridges in the stream; the use of piers that prevent scour of bed, collect drift, and hold back a part of the flow for a time, causing a greatly increased flood wave; the formation of ice gorges; and the failure of dams and reservoir walls."

CHARACTERISTICS OF KANSAS WATERSHEDS.

Reference to the map of Kansas shows that Kansas River and its principal tributaries—the Blue, Republican, Solomon, Saline and Smoky Hill rivers—drain the entire northern half of the state; the Arkansas River drains the southwestern and south central parts; the Marais des Cygnes and the Verdigris rivers occupy smaller basins in the southeastern portion, with the Neosho River in between them, draining a long and narrow basin.

With the exception of the Arkansas River, which has its source in the snow-capped mountain ranges of Colorado, these other rivers head in the Great Plains region, and their water supplies depend solely upon rainfall. The surface storage in these basins is very small, as there are no lakes, ponds or swamps to hold back the flow, and no mountain ranges to hold back the winter precipitation. For these reasons we find the minimum flow of these streams very small and the flood discharges large.

Perhaps the most striking characteristics of these Kansas river valleys are (1) the rolling uplands and (2) the broad, flat bottom lands that are under a high state of cultivation. Through them the rivers meander tortuously, with easy gradients, usually hugging one bank or the other for considerable distances, then swinging back and forth in toward one bank or the other. In eastern Kansas the rivers are fringed with timber, but to the west this becomes more and more scant, practically disappearing at the ninety-eighth meridian, which is also practically the western limit of the flood-producing area.

In the Kansas river basin, the Blue and the Republican rivers, in Kansas, drain areas subject to severe summer rains that make them especially active flood-producing tributaries.

The Republican is wide and shallow, with a rapid descent, and the bed is largely shifting quicksand. It is subject to sudden rises and falls, and occasionally overflows its banks. The Blue also has a considerable fall in its lower reaches, and is the principal power stream in the state.

The banks of the Marais des Cygnes and the Neosho rivers are overhung with heavy growths of timber that are continually being undermined during periods of high water, and the trees are washed into the river channels. Many trees find lodgement on sand bars and add to the formation of objectionable obstructions to the free flow of the water and augment the flood hazard. Much of the bottom land along these rivers is low, so that it does not take a large rise in the streams to cause considerable overflow at various sections. Usually one bank or the other is low, so that the extent of overflowed area during such periods is large.

RAINFALL DISTRIBUTION IN KANSAS.

The mean annual rainfall over Kansas decreases from about 37 inches in the extreme eastern part to about 15 inches in the western part of Kansas. In the eastern third of the state, including the lower Kansas River and the Blue River, the mean rainfall during the crop-growing season, April to September, inclusive, amounts to 25.97 inches. This is the highest average for these months shown in the central Mississippi Valley section. Such a phenomenal high average is accounted for by the severe torrential downpours that occur in this section and which cause the severe floods. The rainfall of May, 1903, that produced the disastrous flood in Kaw Valley totaled more than half the mean rainfall during the crop-growing season. Under normal conditions the rainfall for May is only about 14 percent of the mean annual rainfall.

The precipitation over Kansas is of the plains type, 71 to 78 percent of the annual amount falling during the crop-growing season. It is because of these phenomena that the water problems of the state are so closely interrelated with the problems of agriculture, especially the flood problem.

ENCROACHMENTS ON NATURAL CHANNELS.

Another source of danger during the high-water season that adds to the flood menace, and especially to the loss of life and damage to movable property, for which we have ourselves to blame, is the tendency for congesting the already too-small river-channel capacities, especially in the vicinity of thickly settled communities, by structures of various kinds and other forms of encroachments. This was especially brought into prominence at Kansas City, Kans., by the flood of 1903. It was estimated that the capacity of the natural channel of the Kansas River to carry great floods had been diminished one-half by such encroachments. In a similar way it has been pointed out that the Main Street bridge at Ottawa over the Marais des Cygnes River seriously contracts the channel and acts as a dam to hold back the flood waters of that river for a long distance west of Ottawa. Other instances are too familiar to require mention.

DESTRUCTION WROUGHT BY KANSAS FLOODS.

The destruction wrought by Kansas floods depends a great deal upon the severity of the storm, the nature and extent of the area overflowed, and the opposition encountered by the high water on its path down the valley.

The loss of life in the 1903 flood in Kaw Valley was small considering the population driven from their homes and the rapid approach and vastness of the flood.

Property losses for the 1903 flood were estimated at $22,000,000 in Kansas and Kansas City, Mo., alone, and were considered small when compared with the great value of the property menaced by the flood.

Property losses in Kansas due to floods will always be large, for two reasons: (1) much of the overflowed land is under cultivation and lies in the river bottoms; and (2) many large cities are located in the river valleys in eastern Kansas.

Inundation of these lands and cities is the cause of property losses of various kinds, among which may be enumerated the following: (*a*) Loss of farm stock; (*b*) loss of stock at packing houses; (*c*) loss of growing and stored crops; (*d*) ruin of young orchards; (*e*) spoiling of household furniture and clothing; (*f*) flooding of cellars and loss and damage to goods stored therein; (*g*) flooding of pumping plants; (*h*)

flooding of sewers, with possible serious consequences to the health of the community; and (*i*) crippling of public utilities.

Much loss and damage is done by pressure and the transporting power of flood water. Houses are floated off downstream; drift accumulates at bridges, and these are pushed off their supports; railroad track is undermined or washed out; and often valuable agricultural lands are ruined by the deposition of sand and gravel on them from the overflow.

HISTORY OF FLOOD PREVENTION IN KANSAS.

Destructive floods have occurred so frequently, especially in some of the smaller watersheds, that the most optimistic farmers are disheartened. Unless constructive measures for protection are worked out the psychological effects of such crop failures is readily apparent. Tenants with small capital prefer to farm the less productive uplands rather than experience the uncertainties of loss by inundation of the more fertile bottom lands by these ever-recurring floods. Although disastrous floods do not occur throughout the valleys every year, there are many places where the lands are so low that they rarely escape some damage every season. For these and other reasons, there has been a constantly increasing demand that the state or the federal government investigate these conditions and suggest ways and means for adequate protection from floods.

The following brief history of the growth of this flood-protection movement, presented herewith, shows that substantial progress has already been made in this direction.

Investigations by the United States Geological Survey.

The ground work for all later investigations of the water resources of Kansas was laid as early as 1895 by the United States Geological Survey in connection with its study of the water resources of the United States. "Previous to 1888 matters of this kind were frequently the subject of special inquiry in connection with topographic or geologic surveying, but it was not until the authority was specifically conferred by the acts of March 20 and October 2, 1888, that the subject became one of separate and continuous inquiry."[2] "The work was be-

2. Introduction, 19th Ann. Rept. U. S. Geological Survey, 1898, Part IV, Hydrography, p. 17.

gun in 1888 in connection with special studies of water supply for irrigation. Since the fiscal year ending June 30, 1895, successive sundry civil bills passed by Congress have carried the following item and appropriations:[3]

"For gaging the streams and determining the water supply of the United States, and for the investigation of underground currents and artesian wells, and for the preparation of reports upon the best methods of utilizing the water resources."

Annual appropriations for the fiscal years ending June 30, 1895-1918:

1895	$12,500
1896	20,000
1897 to 1900, inclusive	50,000
1901 to 1902, inclusive	100,000
1903 to 1906, inclusive	200,000
1907	150,000
1908 to 1910, inclusive	100,000
1911 to 1918, inclusive	150,000

In Kansas the State Board of Irrigation, Survey, Experiment and Demonstration coöperated with the work of the United States Geological Survey, with Prof. E. C. Murphy, of the engineering department of Kansas State University, in charge of the work in eastern Kansas, and W. G. Russell, in charge of the work in western Kansas. Prof. O. P. Hood, of Kansas State Agricultural College, coöperated in securing records on Blue River near Manhattan.

From 1895 to 1906 records of discharge of Kansas streams were made at many important points. The long-time records thus secured have been invaluable in assisting in the flood-prevention plans that have been developed or proposed from time to time. These data, which have been published in the several publications of the Geological Survey, many of which are now out of print or no longer easily available, are now being compiled into one volume for ready reference, to be published by the United States Geological Survey as a Water-Supply Paper, entitled "Water Resources of Kansas."

Mention can only be made at this time of the underground investigations that have also been part of the general investigations of the Geological Survey along with the surface waters investigations in Kansas. As geologic conditions modify the distribution of such underground supplies, their survey is more laborious. The published results are, however, impor-

3. Introduction of Water-Supply Papers, U. S. Geological Survey.

tant contributions to the irrigation investigations and the irrigation development of the semiarid portion of the state, which is dependent largely upon the artesian waters for irrigation and water supply.

Investigations by the United States Army Engineers.

No comprehensive plan for flood prevention in the several river basins seems to have been followed in the state until the disastrous flood of 1903 in the Kaw Valley brought the urgent need and the practical value of such a policy forcibly before the consideration of the citizens of Kansas. It is true that in certain localities, where flood conditions were causing considerable damage to the bottom lands, some individual efforts had been made, and still are being made, to prevent overflow, but the majority of the levees thus constructed are too small, do not have the proper cross-section, and are not properly located to serve the best interest of the section effectively.

Prior to the public meetings held by a special board of army engineers in Kansas City, Mo., 1903, after the 1903 flood, no comprehensive plan for flood protection by the municipalities or private interests at Kansas City had been formulated.

"The attitude of the railroads was that, from a business standpoint, they were not justified in investing large sums of money for insurance from excessive floods, as these occurred only at rare intervals, the previous flood being 1844. The municipalities believed it almost hopeless to get effective coöperation from all interested parties, and were endeavoring to make the best of the situation by projecting new grades and levees. Many bridges, however, were being reconstructed without regard to the lesson taught by the 1903 flood."[4]

"The findings of the special board of army engineers were given in three reports, as follows:[5]

"(*a*) Report on harbor lines at Kansas City.

"(*b*) Report on obstructive bridges over the Kansas River.

"(*c*) Report of flood conditions on the Kansas River.

"The matter of flood conditions was investigated at length; the matter of harbor lines was deferred until surveys and further investigations could be made.

"During 1909 and 1910, surveys were made by the United States army engineers, and harbor lines were approved by the Secretary of War, June 24, 1910. . . .[6]

4. From "Preliminary report by Kansas Water Commission on the effect of obstructions to navigation and flood prevention by Kansas City Northwestern Railway Company's bridge on Kansas River at Kansas City, Kansas," August, 1917, pp. 6-7.

5. Senate Document No. 160, 58th Congress, 2d Session.

6. House Document No. 94, 62d Congress, 1st Session, p. 9.

"Kansas River was not generally considered to be a navigable stream prior to 1903, although some work had been done by the federal government on river improvement at its mouth. No supervision of bridges across the Kansas River had been exercised by the government prior to 1903, and none of the bridges were equipped with draw spans. A decision by the United States circuit court, district of Kansas, in a suit between Kaw Valley Drainage District vs. Missouri Pacific and Union Pacific Railroad Companies, definitely settled the status of the river. The court found:

" 'That the Kansas River from its mouth to a point several miles above the city of Argentine is a navigable stream, and that the bridge of the defendant as now constructed and maintained is an obstruction to the navigation thereof.'

"The court required the bridge to be raised and widened, and that all piling, riprapping and other similar obstructions in the channel of the stream under said bridge be removed. Thus was established by a judicial decision the fact that the Kansas River is a navigable stream under the jurisdiction of the War Department.' "[7]

The War Department, through its United States army engineers, has coöperated with the Kaw Valley Drainage District at Kansas City in combining proposed flood-prevention plans and plans for navigation improvements, as far as practicable and feasible, since the formation of that district in 1905.

Kaw Valley Drainage District and Its Fight for Flood Protection at Kansas City, Kans.

The next constructive step forward looking toward the adoption of a state-wide water-conservation policy was the formation of the Kaw Valley Drainage District, organized under the laws of the state of Kansas in the spring of 1905, under chapter 215, Session Laws of 1905, as a permanent body, which was governed by the Kaw Valley Drainage Board. Under the state laws this board was given authority—

"To take charge of and exercise exclusive control over natural watercourses within its territorial limits in the interest of flood protection, and may condemn and cause obstructions in such watercourses to be removed. . . . To have all obstructions wrongfully placed in the channel of natural water courses adjudged public nuisances and abated as such. . . . To prescribe, regulate and fix the height of the superstructures above the water, the length of all spans and the location of the piers of all bridges across watercourses situated in the district."[8]

The jurisdiction of the Drainage Board extends over all lands included in the district subject to overflow, extending from the

7. House Document No. 584, 63d Congress, 2d Session, pp. 32-33.
8. House Document No. 584, 63d Congress, 2d Session, p. 32.

mouth of the Kansas River to about four miles above Turner, Kans. It has powers of taxation, and in that way represents all landowners along that part of the river. Plans for river improvements were formulated and financed by bond issues for the purpose of placing the district in a condition to avoid the consequences of another flood similar to that of 1903. Up to 1917 ten of the eleven bridges in the 734-foot harbor-line section have finally been made to conform to the requirements of the federal government and the Kaw Valley Drainage District. The Kansas City Northwestern Railway Company's bridge alone does not yet conform to these plans.

While the flood situation at several points along the Kansas River has been decidedly improved since the 1903 flood through the activities of drainage districts—such as the Kaw Valley Drainage District at Kansas City, and the North Topeka Drainage District and the South Side Levee District No. 6 at Topeka —no comprehensive plan for relieving the flood situation in the entire Kaw Valley has yet been made. The drift menace is only one of the incidental problems that still threatens the permanent improvements that already have been built.

Investigations by the United States Department of Agriculture in Neosho and Marais des Cygnes Valleys.

In the Neosho and in the Marais des Cygnes valleys, however, comprehensive plans have been made based upon detailed field investigations made by the United States Department of Agriculture, Office of Experiment Stations. The Neosho Valley investigation was made in 1906 and that of the Marais des Cygnes in 1909, both at the urgent petition of numerous residents of these valleys, respectively, who (in the case of the Marais des Cygnes) "urged in the petition that a thorough examination and survey of the valley conditions, for the purpose of ascertaining what works would be needed for the relief of the property owners, would be of great service to the people in their efforts to reclaim their lands."[9]

In consideration of the plans for the proposed improvements, the rainfall records of the United States Weather Bureau, and especially the stream-flow data that have been secured in the past by the United States Geological Survey, play a very im-

9. Introduction, "Reclamation of overflowed lands in Marais des Cygnes Valley, Kansas," U. S. Dept. of Agriculture, Bull. 234, p. 7.

portant part in determining the height of the proposed levees and the areas of the proposed waterways that have to be provided for the safe passage of the flood waters.

The conclusions reached in the Neosho Valley investigation include this statement:

"The data for determining the height of levees and the width of waterway between them are unsatisfactory in many respects. The run-off of the Neosho River after the banks are full has not been determined with any degree of accuracy. The specifications for these two important factors of the flood channel have been made after ascertaining the amount discharged by other streams whose flood flow has been measured quite accurately, and whose watershed is similar to that of the Neosho basin."[10]

It is well to note that the record of Neosho River near Iola, Kans., maintained by the United States Geological Survey for the period 1895 to 1903, was the only long-time stream-flow record that was available for this investigation.

The conclusion reached in the Marais des Cygnes Valley investigation include the following statement:

"There is a great need of accurate gagings and measurements to determine the flood flow of the Marais des Cygnes River. In the absence of such data all computations are, at best, but roughly approximate, and results must be safeguarded by making liberal allowances for unknown factors."[11]

Here, also, the only records of stream flow available upon which to base an estimate of flood discharge were those for the gaging station on Marais des Cygnes River at Ottawa, Kans., maintained by the United States Geological Survey for the period 1902 to 1905.

These two investigations pointed the way for future reclamation work on a large scale and stimulated action by drainage districts organized under the laws of the state. Indirectly they showed the need for a governing body with power to direct and coördinate these internal improvements along the lines of some constructive state-wide conservation policy. The customary method of seeking relief by uncoördinated legislation at each session of the legislature diffused rather than focused responsibility, and was not entirely satisfactory. It was finally decided in 1915 to hold a congress at which all phases of the water problems of the state might be considered at length, to the end that some workable water policy might be formulated

10. "The prevention of injury by floods in the Neosho Valley," U. S. Dept. of Agriculture, Bull. 198, p. 42.

11. "Review and conclusions," in "Reclamation of the overflowed lands in the Marais des Cygnes Valley, Kansas," U. S. Dept. of Agriculture, Bull. 234, p. 43.

that would give shape to future legislation, pave the way for economic development, and be beneficial to the future prosperity of Kansas. Coupled with these internal matters was the growing need for a representative state organization that could work with the federal government in the inland waterways project, of which the state of Kansas is an integral part, that still remains one of the unsolved national economic and engineering undertakings of the future.

The Kansas Flood and Water Congress.

"On July 9, 1915, in response to a general call issued by Governor Capper, there convened at Topeka a meeting of representative citizens from all parts of the state to discuss flood protection.

"The people of Kansas seemed to realize the importance of the flood-prevention problem, and some two hundred business men, representing the civic and commercial bodies and also the large railroad companies, responded to the call. A permanent organization was effected, known as the Kansas Flood and Water Congress.

. . . . . .

"Provision was made for the appointment of representatives from each city and county and from each drainage district, and for the appointment of an executive committee of twelve men, with subcommittees on engineering, legislation, finance, and publicity."[12]

The preliminary report of the engineering committee, by Mr. H. B. Walker, drainage and irrigation engineer, Kansas State Agricultural College, Manhattan, Kans., was the only one submitted by the various committees held in 1916. This report summarizes the conclusions of the engineering committee as follows:

"General Summary.

"1. We believe the coöperation and aid of the federal government is necessary in working out a comprehensive and satisfactory system for flood abatement in Kansas.

"2. We believe a permanent state flood committee is essential in making a comprehensive study of the Kansas flood problem, and we further believe that this committee should be the official body acting for the state in matters relating to state and federal aid.

"3. We urge the reëstablishment of the stream-gaging stations in this state which were formerly maintained by the United States Geological Survey.

"4. We recommend that preliminary action should be immediately formulated for the purpose of enacting adequate state legislation whereby the state would be empowered to make a comprehensive study of the Kansas flood conditions.

12. "Drainage and flood protection," by Robert Waldie, 1917, in *The Kansas Engineer*, 1916-1917, No. 3, p. 61.

"General Discussion.

"*Federal aid essential.* Conservative estimates place the Kansas flood losses at approximately fifty-two million dollars during the past thirteen years. This means that Kansas is sustaining an annual property loss of approximately four million dollars. In addition to these direct losses are many other losses which cannot be given a money value. Not the least of these is the loss of human lives, which has been upwards to one hundred during the past thirteen years. The citizens of the state generally recognize the seriousness of our flood situation and they are looking forward to some proposed plan of relief.

"As a state undertaking, however, the problem appears to be too complicated for a possible economic solution. The principal drainage areas where heavy flood losses have been sustained pass beyond the political boundaries of the state into neighboring states. Some of the streams have their headwaters in Kansas, but are, on the other hand, controlling and important tributaries to the flood conditions in adjacent states. Kansas might propose a state flood plan which would be an economic hindrance to the flood control in neighboring states, and in a similar manner neighboring states might complicate our own problems. It is evident that the aid, coöperation and regulation of the federal government is essential to work out in a comprehensive way a practical plan of relief.

"*Permanent flood committee.* Any plan for flood abatement or relief will affect directly or indirectly the interests of citizens of the state. It is apparent that the cost of flood-protection works must be paid, to a great extent at least, by funds acquired from citizens of Kansas by some method of direct or indirect taxation. As a state, then, Kansas will have a very direct interest in the solution of this problem.

"We believe a permanent state flood committee should be appointed to act officially for the state in matters relating to methods of control, taxation and federal aid. The guiding influence of the federal government is necessary to work out the flood problem without reference to political state boundaries, but the execution of these plans and the solution of local drainage problems will probably depend largely upon the various state governments.

"A comprehensive plan must be systematically executed, and Kansas should be prepared, through some simple method of state organization, to take care of these conditions.

"We believe a state committee, composed largely of engineers, is necessary for the purpose of gathering information for use in federal aid, as well as to act as an official state body, should definite and comprehensive plans of protection be inaugurated.

. . . . . .

Legislation. Kansas laws are not sufficiently adequate to permit the state to engage actively in the solution of our flood problem. As a state we desire federal aid, and we believe the state should fortify its sincerity toward federal aid by enacting laws favorable to coöperative investigations.

"The flood problem of Kansas will not become less complicated with time. In fact, delay means more complications and greater efforts to

secure correct data upon which to formulate methods of control. Investigations may not bring forth an immediately practical solution of our problems, but the data obtained will have a definite future value to the state. We earnestly urge the enactment of such legislation as will enable the state to make a careful study of Kansas flood problems."

These recommendations were embodied in a Water Commission bill that was presented to the 1917 session of the state legislature, and was one of the important legislative enactments of that body.

THE KANSAS WATER COMMISSION ACT.

To fully understand and appreciate the importance of the state-wide water-conservation policy that the state has so recently adopted, the water-commission law is quoted here in full:

CHAPTER 172, SESSION LAWS OF KANSAS, 1917 (PAGE 218).

AN ACT relating to floods, drainage, water power, domestic water supply, navigation, irrigation, and providing for state control of all matters relating thereto and providing for a Water Commission in the state of Kansas.

Be it enacted by the Legislature of the State of Kansas:

SECTION 1. A commission, which shall be known as the Kansas Water Commission, is hereby created for the purpose of investigating and controlling the problems of flood prevention, drainage, domestic water supply, water power, navigation and irrigation in the state of Kansas. But said commission shall not interfere with any drainage system now established in drainage districts created under existing laws.

SEC. 2. The Kansas Water Commission shall be composed of three persons, of which the governor shall be *ex officio* chairman, and two civil engineers, who shall be, or be qualified to be, at least associate members of the American Society of Civil Engineers, and shall be appointed by the governor to hold office for four years, or until their successors are appointed and qualified, and who shall be eligible for reappointment and may be removed at any time by the governor for cause only. As soon as this act shall be in force the governor shall appoint one member whose term of office shall expire January 1, 1921, and one member whose term shall expire January 1, 1919; thereafter the governor shall appoint one member on the first day of January in each odd-numbered year, and whose term of office shall expire on the first day of January four years thereafter. The members of said commission shall serve without salary or other compensation, but the members thereof shall be allowed their actual traveling expenses when on official business of the commission. Employees of the state may be appointed members of this commission without vacating their positions or without change of compensation.

SEC. 3. This commission is hereby authorized to secure such expert assistance, clerical and other help, and at such compensation as may be necessary to properly carry out the provisions of this act.

SEC. 4. As soon as practical after organization the commission shall, in conjunction with the federal government, by way of securing financial and professional aid and assistance, work out a systematic general plan for the complete development of each watershed in the state in order to secure the most advantageous adjustment of the interest involved in matters of floods, drainage, irrigation, water power and navigation. Where any department of the federal government is now or hereafter may be engaged in the development of plans, effecting any of the subjects referred to in this act this commission may coöperate with such federal department. Water development of all kinds throughout the state shall conform to the general plans adopted by the commission.

SEC. 5. This commission is hereby authorized and directed to establish and maintain river gaging stations and to make such surveys and other investigations as may be necessary to a complete knowledge of the subjects herein assigned to it for investigation.

SEC. 6. The following principles shall guide the commission in its decisions and plans: (*a*) Surface or underground waters of the state may be appropriated by the federal government by civic decisions, by corporations, and by individuals upon application to the commission, and in accordance with the rules and regulations it may prescribe. Such appropriations shall not constitute absolute ownership of such waters, but shall remain subject to the principle of beneficial use. (*b*) Where appropriations of water for different purposes conflict they shall take precedence in the following order, namely: domestic and transportation water supply, irrigation, industrial uses, water power. In each of these decisions prior application is to govern in making allotments. (*c*) Appropriation in excess of the reasonable needs of the appropriators not to be allowed. (*d*) Waters appropriated for irrigation are to become appurtenant to the lands to which they are applied, and underground waters for all purposes to become appurtenant to the lands under which they flow.

SEC. 7. The commission shall study the laws of the state relating to floods, drainage and irrigation, with a view to making such revisions as may be necessary to accomplish the ends prescribed in this act, and they shall report the results of their investigation and make such recommendations as they may deem proper to the legislature from time to time.

SEC. 8. The commission and its agents shall have the power of entry on private lands for the purpose of carrying out the provisions of this act.

SEC. 9. All money now in the state treasury received from, or that may hereafter be received as compensation for sand taken from any navigable stream, except such amounts as drainage districts may be entitled to under the law, shall be placed in a separate fund, which shall be known as the Water Commission fund, and from which fund all expenses and obligations of the Water Commission shall be paid.

SEC. 10. The salaries of all employees of the Water Commission shall be fixed by said Water Commission.

SEC. 11. To carry out the provisions of this act and to coöperate with the federal government in all matters pertaining hereto, there is hereby appropriated for the remainder of the fiscal year ending June 30, 1917, the sum of $1,000, or so much thereof as may be necessary; for the fiscal

year ending June 30, 1918, the sum of $3,000, or so much thereof as may be necessary; and for the fiscal year ending June 30, 1919, the sum of $3,000, or so much thereof as may be necessary, which shall be expended under the direction of the commission.

SEC. 12. This act shall take effect and be in force from and after its publication in the official state paper.

This act was published in the official state paper on March 24, 1917.

THE KANSAS WATER COMMISSION: A REVIEW.

The Law.

You will observe that this Water Commission law is, above all, brief and comprehensive, and presents a clear and concise statement of the state-wide water-conservation policy for Kansas. You will note further that the law provides for a commission with powers to *investigate* and *control* specific water problems: flood prevention, drainage, domestic water supply, water power, navigation, and irrigation (section 1). The magnitude and importance of such a program is worth remembering. The present law is the foundation upon which to add additional legislation as needed to bring these several projects to successful completion.

The Organization.

Section 2 provides for the organization of a commission of three members: the governor as *ex officio* chairman, and two civil engineers, "who shall be, or be qualified to be, at least associate members of the American Society of Civil Engineers." It is obvious to a body of engineers that these problems before the Water Commission are engineering matters of a high order, that will require broad and intelligent treatment in their solution. It is altogether fitting that the high standards of the American Society of Civil Engineers should be adopted for the personnel of the commission.

It may seem inconsistent that "The members of said commission shall serve without salary or other compensation," or that "employees of the state may be appointed members of this commission without vacating their present positions or without a change of compensation." These matters are involved in the financing of the Water Commission, which is of particular importance.

How Financed.

Section 9 of the Water Commission law provides that—

"All money now in the state treasury received from, or that may hereafter be received as compensation for sand taken from any navigable stream, except such amounts as drainage districts may be entitled to under the law, shall be placed in a separate fund, which shall be known as the Water Commission fund, and from which fund all expenses and obligations of the Water Commission shall be paid."

In other words, the investigations of the Kansas Water Commission are to be financed from the revenue derived through the workings of the so-called Kansas sand law, passed by the 1913 legislature, chapter 259, Session Laws of Kansas, 1913, which reads in part as follows:

"AN ACT relating to the sale and taking of sand, oil, gas, gravel, mineral and any other natural product whatsoever from the bed of any river which is the property of the state or any island therein. . . . prescribing certain powers and duties of public officers in relation thereto; . . ."

Under the provisions of this act the natural products that had heretofore been taken by private concerns without any revenue going to the state treasury are now considered natural resources belonging to the state, for which royalties, determined by the Executive Council, must be paid into the state treasury, ways and means being provided to enforce this law. The exception mentioned in section 9 of the Water Commission law is covered in section 2 of the sand act, as follows:

"Where any navigable stream extends into or through any drainage district in the state, organized under chapter 215 of the Session Laws of 1905, and the amendments thereto, the board of directors of such district shall be entitled to one-third of the proceeds of such natural products or minerals which the state may sell from within or beneath a portion of the channel of such streams lying within such district, and said one-third of the proceeds arising from any such sale shall be paid to the treasurer of such drainage district and shall be expended only by such district for any of the purposes for which such district was created."

Litigation Over the Kansas Sand Law and Its Bearing on the Financing of the Kansas Water Commission.

The Kansas sand law was made inoperative by litigation that was still pending before the supreme court of Kansas at the time the Kansas Water Commission bill was under consideration. The means to immediately finance the work of the commission were, therefore, not available, so emergency measures had to be adopted pending a favorable decision on

the constitutionality of the Kansas sand law, in order that the state-wide water-conservation policy, as embodied in the Water Commission bill, could be adopted by the 1917 legislature. For this expediency it became necessary to require the commissioners to serve without compensation, and also to enlist the support of engineers already in the employ of the state in responsible positions to assume these additional reponsibilities, without compensation, in addition to their regular duties.

To provide for necessary field investigations for stream gaging, and to enlist the coöperation of the federal government in this work, small appropriations from the general fund were made for the balance of the fiscal year 1917, and for the fiscal years 1918 and 1919, respectively.

Constitutionality of the Kansas Sand Law Determined.

The supreme court of the state of Kansas in 1917 ruled that the Kansas sand law was constitutional. However, the case was appealed to the United States supreme court. On November 26, 1917, the United States supreme court rendered a decision upholding the constitutionality of the Kansas sand law, so that the state of Kansas could then assert its sovereignty to the "bed and channel of any river in this state or bordering on this state to the middle of the main channel thereof and all islands and sand bars lying therein," certain legal exceptions to the contrary being specifically mentioned in the law (section 6, chapter 259, Session Laws of Kansas, 1913).

Limitations of the Present Wording of the Water Commission Law.

The attorney-general has ruled that section 9 of the Water Commission law (relating to financing the work from the revenue derived from the sand royalties) does not make the sand royalties immediately available, but that these moneys are held in trust, in a Water Commission fund, subject to future appropriations by the state legislature. This decision precludes the formation of a larger organization by the Water Commission to advance the work of the commission until an appropriation from the Water Commission fund is made by the next legislature. Until then the investigations will be restricted to the small appropriations made by the last legislature and through the coöperation with the United States Geological Survey.

FUNCTIONS OF THE KANSAS WATER COMMISSION.

The functions of the Kansas Water Commission are two: (1) *Investigation* and (2) *control* of the complete water developments of all kinds throughout the state. These will have to be planned "to secure the most advantageous adjustment of the interest involved in matters of flood, drainage, irrigation, water power and navigation," as pointed out in section 4 of the Water Commission law.

Before plans can be made for controlling these several water problems, each one a big undertaking in itself, the problems themselves must be studied carefully. Certain investigations have already been made; other investigations will also have to be made, and all coördinated into the general scheme of the Water Commission (section 4). This will require a trained organization to secure and digest these physical data. It must be kept constantly in mind that intelligent control of these problems can only result from field investigations carefully planned and executed, and through critical analyses of their results.

Investigation of the Flood Problem.

The flood-control problem for eastern Kansas is one of the most ambitious undertakings that the Kansas Water Commission has before it for solution. Let us consider for a moment some of the investigations required for developing such a project for Kaw Valley. With the "factors determining maximum discharge" in mind (see p. 7), it is clearly seen that certain physical data must be available to determine a comprehensive plan for the control of the entire valley. Among these data are the following:

(1) Detailed topographic survey of Kaw Valley, including Kansas River and its principal tributaries, extending to the limits of the flood-producing area, and showing—

(*a*) Plan; (*b*) profiles of the bed and water surface referenced to a datum plane, preferably mean sea level; (*c*) extent of flooded areas by different floods; (*d*) location of debris, such as old bridge steel, piers, and similar wreckage lying in the bed of the river; (*e*) character of river banks; (*f*) information from local sources of extent and magnitude of past floods.

(2) Rainfall data for Kaw Valley.

(3) Run-off (stream-flow data) for main river and principal tributaries for various points in watershed.

(4) Investigation of possible reservoir sites.

(5) Analysis and coördination of all physical data.

(6) Analysis of possible methods of protection.

The need for starting some of these investigations without delay was appreciated when the Water Commission bill was under consideration. Section 5 provides: "This commission is hereby authorized and directed to establish and maintain river-gaging stations and to make such surveys and other investigations as may be necessary to a complete knowledge of the subjects herein assigned to it for investigation." Section 4 also provides that ". . . where any department of the federal government is now or hereafter may be engaged in the development of plans, effecting any of the subjects referred to in this act this commission may coöperate with such federal department. . . ."

Mention has already been made of the pioneer work of the United States Geological Survey in the investigation of stream flow in the several drainage basins of Kansas during the period from 1895 to 1906, in coöperation with the State Board of Irrigation, Survey, Experiment and Demonstration. The practical value of the records then secured has been demonstrated conclusively in the plans for flood protection at Kansas City, and the proposed flood-protection plans for the Neosho and the Marais des Cygnes valleys. Also the need for a great deal more of these records has been realized in connection with these plans. Due to the fact that the work of the United States Geological Survey was discontinued in Kansas in 1905 and 1906, no reliable records of the flood discharges of 1908 and 1915 are available.

Cooperation with the United States Geological Survey.

On May 11, 1917, a coöperative agreement was made between the United States Geological Survey and the Kansas Water Commission for the investigation of the water resources of Kansas. On June 1, 1917, the United States Geological Survey opened a district office at room 25, Federal Building, Topeka, Kans., with Roger C. Rice as district engineer.

The joint work of the Kansas Water Commission and the Geological Survey has been confined to the establishment of river-gaging stations on the more important rivers in eastern Kansas, located at strategic points selected as part of the systematic investigation of the hydrometric problems of these drainage basins. The list of the proposed river-gaging stations

to be established in the near future is given herewith. Those already established are noted.

River-gaging Stations in Kansas, Established or Proposed by the Kansas Water Commission, in Coöperation with the United States Geological Survey.

KAW VALLEY:
- Kansas River basin:
  - Kansas River at Ogden. (Established June 19, 1917.)
  - Kansas River at Topeka. (Established June 12, 1917.)
  - Kansas River at Bonner Springs. (Established July 8, 1917.)
- Blue River basin:
  - Blue River—Marysville.
  - Blue River—Randolph.
- Republican River basin:
  - Republican River—Republic.
  - Republican River at Wakefield. (Established June 21, 1917.)
- Solomon River basin:
  - Solomon River near Bennington. (Established October 1, 1917.)
- Saline River basin:
  - Saline River—Lincoln.
- Smoky Hill River basin.
  - Smoky Hill River—Ellsworth.
  - Smoky Hill River—Solomon.

MARAIS DES CYGNES VALLEY:
- Marais des Cygnes River—Ottawa.
- Marais des Cygnes River—La Cygne.

NEOSHO VALLEY:
- Cottonwood River—Saffordville.
- Little Neosho River—Council Grove.
- Neosho River near Iola. (Established October 12, 1917.)
- Neosho River—Oswego.

VERDIGRIS VALLEY:
- Verdigris River—Independence.

ARKANSAS VALLEY:
- Arkansas River—Syracuse.
- Arkansas River—Wichita.

These proposed river-gaging stations will be established and the work expanded as fast as funds will permit. The gaging station on Neosho River near Iola is the only one of the established gaging stations equipped with a self-recording gage, as such installations in Kansas are expensive, owing to the great range of stage between low and high water and the first cost of permanent structures. At all gaging stations now in operation current meter measurements of discharge are being made, in order to determine the daily discharge of the streams at these points.

The financial limitations on the present work require that the organization for this stream-gaging investigation be limited to the activities of the district engineer. As each spring brings a recurrence of serious flood possibilities, this organization is entirely inadequate to cope successfuly with the flood problem in obtaining the necessary flood data for the future work of the Kansas Water Commission.

Cooperation with the United States Weather Bureau.

The United States Weather Bureau maintains rainfall stations in every county in the state of Kansas, and also maintains river gages at the following points on rivers in Kansas in connection with the river forecast work:

United States Weather Bureau River Gages in Kansas.

KAW VALLEY:
- Kansas River—Wamego.
- Kansas River—Topeka.
- Blue River—Blue Rapids.
- Republican River—Clyde. (To be established in the spring of 1918, to replace the discontinued station formerly located at Clay Center.)
- Solomon River—Beloit.
- Smoky Hill River—Lindsborg.
- Smoky Hill River—Abilene.

NEOSHO VALLEY:
- Cottonwood River—Emporia.
- Neosho River—Neosho Rapids.
- Neosho River—Iola.
- Neosho River—Oswego.

ARKANSAS VALLEY:
- Arkansas River—Dodge City.
- Arkansas River—Great Bend.
- Arkansas River—Wichita.
- Little Arkansas River—Sedgwick.

It was the earnest desire of the Kansas Water Commission that the stream-gaging work of the United States Geological Survey be coördinated as far as possible with the river forecast work of the United States Weather Bureau. This service is recognized as invaluable by citizens and industries within the areas subject to disastrous floods. Definite progress in this direction has been accomplished for the Kaw Valley.

The central office of the Weather Bureau has made Topeka the center of river forecast work for Kaw Valley. Mr. S. D. Flora, meteorologist in charge at Topeka, has been granted authority to make use of such gaging stations that are maintained by the United States Geological Survey as are needed to perfect the river forecast work. The central office has also expressed its willingness to assist the Kansas Water Commission and the United States Geological Survey further by cooperating in the installation of a long-distance recording river gage on Kansas River at Topeka. This will materially assist in the flood studies of the Kaw Valley.

Other Cooperation.

The stream-gaging work of the Kansas Water Commission and the United States Geological Survey is receiving the support of other state organizations also. The North Topeka Drainage District and the South Side Levee District No. 6 at Topeka are now constructing a suitable concrete well and shelter for a long-distance recording river gage on Kansas River at Topeka for the Kansas Water Commission, the United States Geological Survey, and the United States Weather Bureau. It is hoped that other automatic gage installations will be installed through similar coöperation.

STREAM GAGING IN KANSAS.

Reference has been made to the stream-gaging investigations of the United States Geological Survey in Kansas, to the establishment of gaging stations, and the importance of having stream-flow records for use in the work of the Kansas Water Commission. Undoubtedly, certain queries regarding the nature of this work occur to you which it may not be out of place to anticipate at this time.

Without going into the subject of stream gaging extensively, as this is covered in detail by many excellent authorities, it is well to have in mind a few of the fundamental principles governing the selection, construction and operation of a gaging station and the field and office procedure necessary to secure these records.

Reconnaissance for Gaging Station.

A gaging station (Pl. II, *B*) consists of suitable equipment located on a stream where the total flow is determined.

A reconnaissance, or inspection, of a stretch of the river in

the vicinity of the proposed gaging station is first made for the purpose of selecting the best location for the gage and the measurement section. Usually these are at about the same point on the river, but if there is no inflow or outflow for a considerable distance the measurement section may be located upstream or downstream from the gage. Among the chief characteristics governing a desirable site for a gaging station are these: A fairly straight stretch of river for some distance, with the flow confined to a definite channel; banks high and not subject to overflow; where natural flow conditions are *steady* and the velocity measurable; where the natural flow is controlled by a riffle or outcropping of rock across the channel to insure permanency in the stage-discharge relation (the importance of this relation will be spoken of later). However, locations within the influence of power dams are avoided, as the stage-discharge relation is affected by regulation at the dam. A location within the influence of backwater from a large tributary is also avoided, as such conditions affect the stage-discharge relation and introduce complications in the interpretation of the base data.

Gaging stations located in Kansas are far from the desired ideal, for the following reasons: (1) The river banks are low, and at high stages overflow extensively; (2) the sandy river beds shift continually, especially during high water. The relation between stage and discharge, therefore, becomes unstable, so that frequent discharge measurements are needed to define it; (3) reliable discharge measurements are difficult to obtain at high stages.

As records of discharge are essential for improving these unfavorable river conditions, gaging stations have to be established and operated with as high an accuracy as possible under the existing conditions. It is obvious that such stations are more expensive to operate and maintain than those where hydrometric conditions are more favorable.

Construction of Gaging Stations.

In general, a gaging station requires the following equipment:[13]

1. A gage or gages for determining fluctuations of stage.
2. Bench marks for referring the gages to a fixed datum.

13. "Equipment for current meter gaging stations," by G. J. Lyon, U. S. Geol. Survey, Water-Supply Paper No. 371, p. 7.

3. Structures from which discharge measurements are made.
4. Cable and stay line to hold meter in a vertical position when soundings and velocity observations are made.
5. Graduated lines to indicate the points of measurement.
6. Artificial structures, at places where natural control is ineffective, to regulate the relation between stage and discharge.

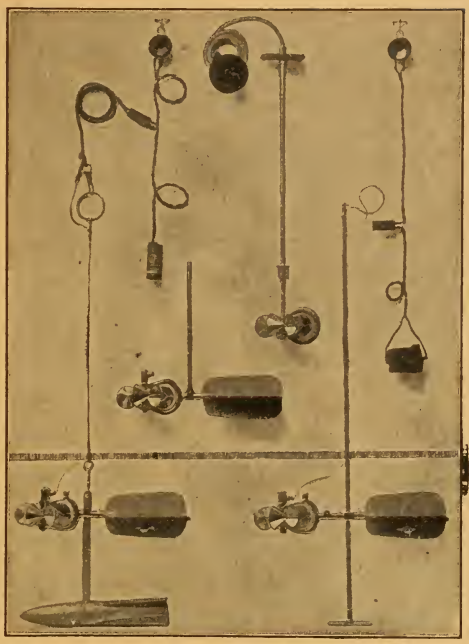
"Although no one form of any of these items is indispensable, there are certain standard types that can, as a rule, be most economically installed and that not only facilitate the making of observations but insure more accurate results."

GAGES. Two classes of gages are used by the United States Geological Survey on river work to measure the fluctuations of the water level. These are nonrecording and recording gages. Nonrecording gages in common use are the vertical-staff gage, the inclined-staff gage, the float gage, and the hook gage. These have to be read directly at stated intervals and require the service of an observer, who lives, usually, in the vicinity of the gage.

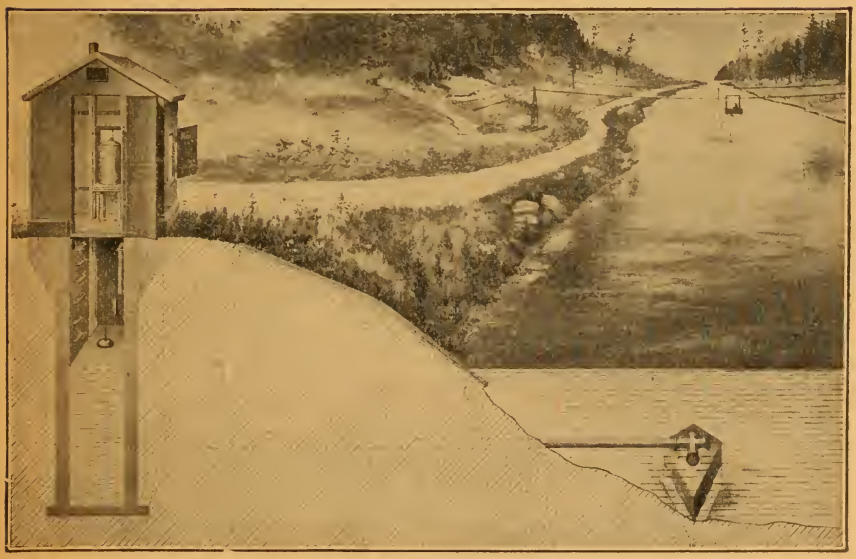
Recording gages (Pl. III, *A*) obtain the record of the stage by some form of mechanism and operate independently of an observer. They make a record of stage, either continuously by a curve, the coördinates of which indicate the time and the stage, or by a device that prints at regular intervals of time.

Often the selection of a suitable gaging station depends primarily on whether or not an observer is available. The recording gage, however, allows the gaging station to be selected at the best location on the river, which is usually isolated.

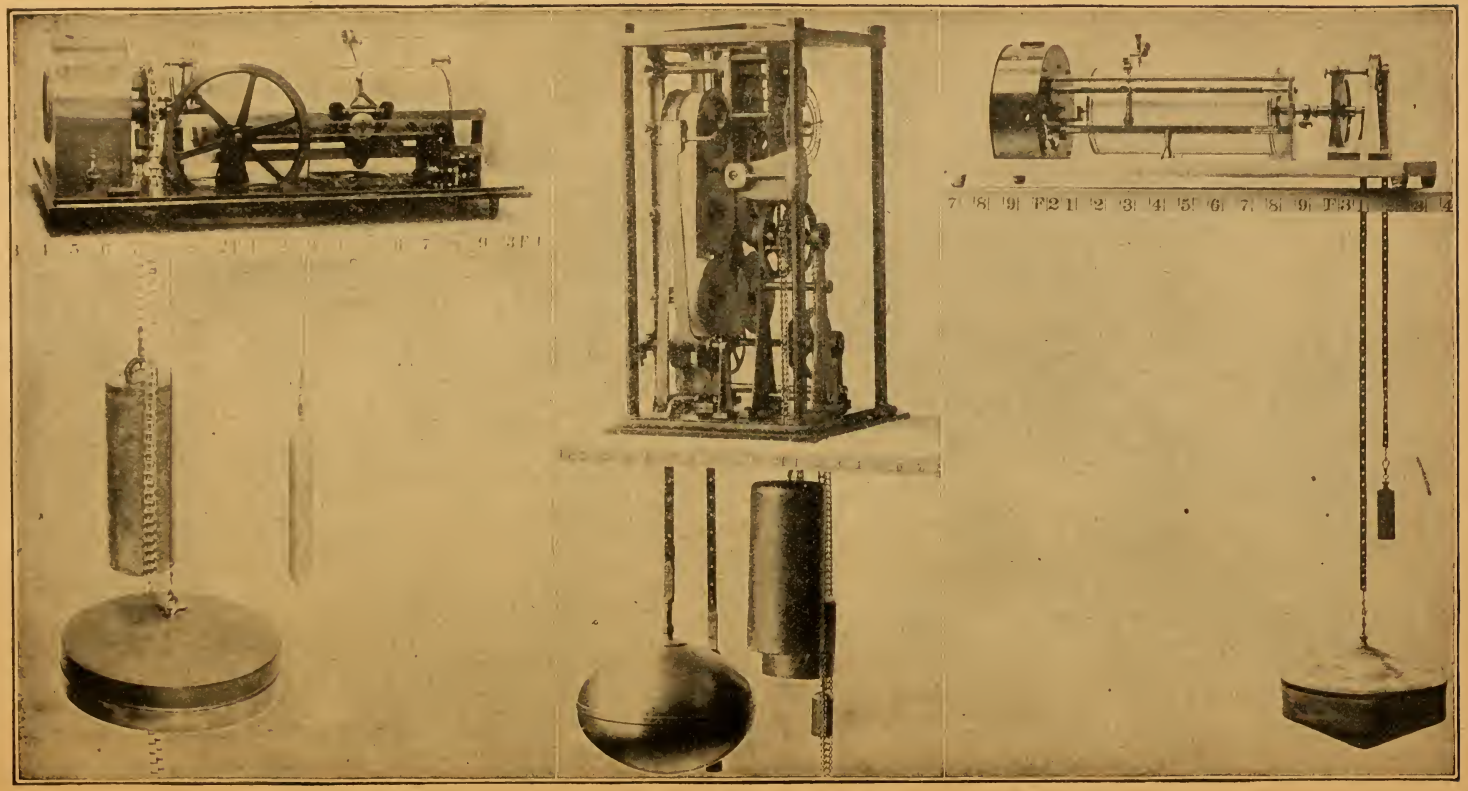
In the past few years recording gages have been largely replacing the nonrecording gages on important investigations. This change has come about through a better appreciation of the value of stream-flow records, the improvement of recording gages that have been put upon the market, and the demand for more accurate determinations of stream flow by coöperating parties. On streams utilized for power purposes it was found upon investigation that the diurnal fluctuations in stage caused by the regulation of the flow by power plants were such that the mean flow for 24-hour periods could not be correctly computed from one, two, or several readings of a nonrecording gage a day, as the form of the water-surface graph was influenced by the regulation. This is also true for all streams subject to rapidly rising or falling stages, as, for example, during periods of high water; a definite knowledge of the shape



A. PRICE CURRENT METERS.



B. TYPICAL GAGING STATION.



A. STEVENS. *B.* GURLEY PRINTING. *C.* FRIEZ.

WATER STAGE RECORDERS.

of the graph is essential for accurate computation of the mean daily discharge. Where it is important to know the crest discharge, unless a recording gage is in operation, the peak height is often not observed, so that it is not possible to determine the crest discharge accurately.

Measurement of Discharge: The Current Meter.

The determination of the discharge of a stream involves the measurement of two quantities: area of the cross-section and the mean velocity of flow. The practice of the United States Geological Survey is to measure the velocity of flow *indirectly* by means of a current meter, an instrument consisting of a wheel with cups or vanes, so constructed that the impact of the flowing water causes this to revolve, the number of revolutions being indicated by means of some form of recording device. The instrument has been previously rated, so that for a given number of revolutions in a given time the equivalent velocity of the flowing water is readily calculated. Current meters may be divided into two classes: (1) those of the Price meter type, in which the cups revolve about a vertical axis; and (2) those of the Haskell or the Fteley type, in which the vanes revolve about a horizontal axis.

The Price current meter (Pl. II, *A*) has been largely developed and extensively used by the United States Geological Survey in its hydrometric investigations of the United States and the territories of Hawaii and Alaska. In its present improved form it may be used to measure all sizes of streams. The meter outfit has also been designed to meet the demand for lightness, compactness, durability and strength.

Measurement of Discharge: How Made.

Discharge measurements may be made by wading or by operating the current meter from a bridge or from a movable car suspended on a cable stretched across the stream. At low stages measurements are usually made by wading, as this enables the selection of a gaging section upstream or downstream from the gage at which the conditions are better for determining the discharge than at the regular high-water section. A tag line is stretched across the stream to mark the points at which soundings and velocity observations are observed, which are made by the engineer, who wades into the stream with

the current meter fastened to a graduated rod. At high stages, when the meter is used on an insulated cable, it is necessary to add lead weights to the meter hanger to keep the meter submerged. Torpedo-shaped weights have been designed, as these offer a minimum of resistance to the water.

Measurement of Discharge: The Stage-Discharge Relation.

Each discharge measurement is referenced to the gage, and a sufficient number of measurements are made at different stages to develop the relation between the stage (gage height) and the discharge. These measurements, when plotted with gage heights as ordinates and discharge as abscissæ, usually define some representative curve, generally parabolic in shape, that is called the "rating curve" or the "stage-discharge relation." When the control for the gage is permanent, this relation between the stage and discharge shows little change from year to year. Where such favorable conditions are known to exist it is possible to anticipate this relation by so arranging the field work that measurements may be secured at definite stages that will be of greatest value in developing the curve. In this way a minimum of field work is required, and the cost of operation for the station is low. After the stage-discharge relation has been well defined for such a gaging station, only occasional measurements are required to check the rating curve from year to year.

Unfortunately, such favorable stream-gaging conditions are the exception, rather than the rule, for Kansas rivers. It is necessary to keep on making measurements and "rerating" the gaging stations, as the unstable river beds do not yield permanent relations between stage and discharge. Not only is this an endless procedure, but the occasional high-water periods so alter river channels that the stream-gaging work of past years is usually of little assistance in the development of new rating-curve relations. Failure to secure needed high-water measurements in a field season may make it impossible to determine the stage-discharge relation for these high-water periods.

PUBLICATION OF RESULTS OF STREAM GAGING.[14]

The base data collected each year at the United States Geological Survey gaging stations consist of records of stage, measurements of discharge, and general information used to supplement the gage heights and discharge measurements in determining the daily flow.

From the discharge measurements rating tables are prepared that give the discharge for any stage, and these rating tables, when applied to the gage heights, give the discharge from which the daily, monthly and yearly mean discharge is determined.

The data presented for each gaging station in the area covered by the several Water-Supply Papers—through which medium these data are made available for the public—comprise a description of the station, a table giving results of discharge measurements, a table showing the daily discharge of the stream, and a table of monthly and yearly discharge and run-off. If the base data are insufficient to determine the daily discharge, tables giving gage heights and the results of discharge measurements are published.

The description of the station gives, in addition to statements regarding location and equipment, information in regard to any conditions that may affect the constancy of the stage-discharge relation, covering such subjects as the occurrence of ice, the use of the stream for log driving, shifting channel, and the cause and effect of backwater; it gives also information as to diversions that decrease the flow at the gage, artificial regulation, maximum and minimum recorded stages, and the accuracy of the records.

These data in the published reports cover the year beginning October 1 and ending September 30. At the 1st of January, in most parts of the United States, much of the precipitation in the preceding three months is stored as ground water, in the form of snow and ice, or in ponds, lakes and swamps, and this stored water passes off in the stream during the spring break-up. At the end of September, on the other hand, the only stored water available for run-off is possibly a small quantity in the ground; therefore, the run-off for the year beginning October 1 is practically all derived from precipitation within that year.

The hydrometric investigations of the United States Geological Survey have been carried on continuously since 1888, and the results of these have been published in the several annual publications. Attention is called to the many special Water-Supply Papers that have been published in recent years, in which long-time records have been compiled and published in separate volumes for the convenience of the engineering profession and others, who have occasion to make extensive use of such data. As previously mentioned, the long-time records of stream flow of Kansas streams, secured during the period

14. Abstracted from "Explanation of data," Water-Supply Paper No. 408, Part VIII, U. S. Geol. Survey, "Western Gulf of Mexico Basins," 1917, pp. 9, 10.

1895 to 1906, will be brought together in one volume in the near future, and will include also the valuable river-gage records of the United States Weather Bureau and the long-time records of rainfall that that bureau has collected. This Water-Supply Paper will be known as "The Water Resources of Kansas," and will, it is believed, prove of great value to engineers who have to deal with water problems in this state.

Summary and Conclusion.

Within the limited scope of this paper an endeavor has been made to present before The Kansas Engineering Society the far-reaching importance of an early solution of the flood problem and its relation to the agricultural development of Kansas, especially under present war-time conditions. The cause and effect of disastrous floods in the state have been considered, together with the relief measures that have been taken by private individuals, and through the coöperation of private, state and federal organizations. The growth of a sentiment toward the formulation of a state-wide water-conservation policy has been sketched, culminating in the deliberations of the Flood and Water Congress and the creation of the Kansas Water Commission, in 1917. The importance of the adoption of this policy, as pointed out in a brief analysis of the Water Commission act, and the need for future action by the state legislature to properly finance the work of the Commission were explained in some detail. The pioneer investigations of the United States Geological Survey during the period from 1895 to 1906, and the renewal of these investigations of stream flow in 1917, in coöperation with the Kansas Water Commission, together with some considerations of the nature and the scope of these investigations, conclude the subject under consideration.

In conclusion, it is the desire of the co-authors that the subject matter covered in this paper be fully discussed by The Kansas Engineering Society, as it is only through such means that the constructive policy of the Kansas Water Commission can be materially guided and assisted to insure the greatest benefits to the greatest numbers.

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